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EXPERIMENTAL INVESTIGATION ON THIN SHEETS OF SS316L IN GAS TUNGSTEN ARC WELDING PROCESS

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ABSTRACT

The grades of stainless steel have several applications such as aerospace, medical, power plants, and automobile industry. Especially stainless steel 316L (SS316L) has been successfully utilized in many sectors because of its excellent corrosion resistance, self-healing property, biocompatibility, high fatigue life and creep resistance. This reported work is a study of SS316L in gas tungsten arc welding (GTAW) in order to enhance the strength of the weldment. The GTAW butt joint of SS316L was subjected to microhardness measurement. The results show that fusion zone has a high hardness number when compared to base material and heat affected zone has heterogeneous hardness distribution. Tensile results of butt joint and the base material of SS316L indicates that welded material has more tensile strength than the base material which shows that the weld is of high quality.

KEYWORDS: GTAW, Micro Hardness, SS316L & Tensile Test

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Original Article

INTRODUCTION

Stainless steel has been widely used for its main properties such as self-healing, fire resistance, strength to weight ratio. Stainless steel is a metallic alloy consist of the notable amount of chromium which induces the self healing property, and maximum carbon content of 1.2% (according to European Standard EN 10088) and other metal elements such as nickel and molybdenum [8]. Stainless steel has better joint efficiency, low fabrication cost and has efficiency in metal joining processes, and these qualities are very much considered for structural applications [1]. Because of these properties, they have been utilized in spectrum applications such as rail coach manufacturing, automotive, civil constructions, nuclear reactor, thermal power plants, heat exchangers and chemical industries[1][8]. Still, SS316L poses many difficulties in manufacturing especially in welding such as sensitization of weld pool area under high temperature which will lead to oxidation and hot cracking of weld metal while solidification. SS316L can be welded in GTAW, plasma arc welding (PAW), submerged arc welding(SAW), laser beam welding (LBW) and electron beam welding process (EBW). Even though most of the welding techniques have their own limitations and demerits. Like PAW produces a large heat affected zone even with lower power density. While submerged arc welding cannot be used to weld circumferential pipes. Electron beam welding is more expensive and requires high vacuum chamber with the precise arrangement of materials and even the slightest beam deflection will result in misalignment of joints. Similarly, laser beam welding is an expensive and slight error in alignment causes joint errors. Electro slag welding with high energy heat input causes coarse grains infusion zone and in heat affected zone which leads to poor weld quality. And GTAW is economical when

compared with other welding processes and able to produce comparatively better weld quality. It is found to be the most versatile of all welding methods. Hence GTAW was chosen for welding of SS316L. R. Mishra et al.[1] studied the weld abilities of SS202, 304, 310 and 316 in GTAW and GMAW processes. And they found that welded specimen of GTAW has better physical properties compared to GMAW process. Sanjeev Sharma et al.[2] investigated the change in mechanical properties by varying different input parameters on Austenitic SS202 grade, using GTAW. They inferred that the input parameter welding current has the maximum influence on the output characteristics. W. Chuaiphan et al.[3] examined the effect of welding speed on microstructures, mechanical properties and corrosion behavior of GTAW. The conclusion was high welding speed exhibited higher tensile strength and elongation, high hardness and smaller weld bead size. Shinde et al. [4] inspected the effect of welding parameters in MIGW, the major parameters were the gas flow rate of the shielding gas, welding current and arc voltage were evaluated in terms of tensile and yield strength of butt-welded mild steel plates. Results showed that higher order of parameters such as welding current and gas flow rate of shielding gas had affected the tensile and yield strength more than other parameters. Chellappan Muthusamy et al.[5] studied the welding of 6 mm thick AISI 410S LSMSS under different heat input parameters, it was inferred that the rise in heat input decreased the strength in welded joints, the hardness of the welded joint was increases but insignificantly. Subodh Kumar et al.[6] reported the influence of input parameters on output characteristics of SS304 welded joints. The result implies that low heat input exhibited high tensile strength compared to high and medium heat inputs. It was further observed that the average dendrite length and inter-dendritic spacing in welded zone increase with the increase in heat input, which affects the tensile properties. L. Zhao et al.[7] studied the behavior of nitrogen content in gas tungsten arc welded high nitrogen stainless steel (HNS). The inference was that nitrogen content increases due to the presence of nitrogen content in the shielding gas containing Ar and N2 increased under the same heat input of welding. The Nitrogen content decreases when pure shielding gas (99% argon) is present. Based on the literature survey, it is noted that previous studies were carried out on the metallurgical point of view and fractographical perspective. But only a few works were performed in terms of hardness distribution and behavior of plastic deformation in gas tungsten arc welded SS316L. Hence this reported work is concentrated on the abovementioned characterization. Thereby tensile tests were performed in the universal testing machine and microhardness tests were carried out on Vickers microhardness

EXPERIMENTAL WORK

Figure 1: Welding Setup of Gas Tungsten Arc Welding Process

Figure 2: Fixture used for Gas Tungsten Welding Process

The material used in this experimental investigation is 2mm and 1.6mm thin sheets of stainless steel 316L (SS316L). The chemical composition of SS316L is shown in table 1. The integrity of the GTAW process is influenced by a number of parameters such as welding speed, welding current, stand of distance, electrode angle, gas flow rate, torch angle, and types of shielding gas mixture. The welding setup used to perform trials and the joint is shown in figure 1. A number of the bead on trials were conducted on 2mm thickness SS316L by varying different welding parameters, From the trials, it was noted that welding speed and welding current have a significant effect in weld bead geometry when compared to other

welding parameters. The selected range of welding speed and welding current were decided from the experience gained from trials and which is shown in table 2.

Table 1: Chemical Composition (in Wt. %) of SS316L

Name of the Element	C	Mn	P	S	Si	Cr	Ni	Mo	N	Fe
Composition (%)	0.03	2	0.045	0.03	0.75	17	13	2.5	0.1	Balance

Initially, sheets of SS316L was cleaned using a wire brush to remove dirt and corrosion and both sides of SS316L sheets were cleansed by acetone to avoid oil and other sedimentations. In order to avoid distortion and to provide sufficient shielding gas, the specimens were held in a fixture while welding which is shown in figure 2. Other welding parameters of arc length, shielding gas flow rate, electrode angle were maintained as 3mm, 10lpm, 45° respectively while varying the values of welding speed and welding current to conduct nine beads on trials in SS316l 2mm sheets. EDM(Electrical discharge machining) wire cutting was utilized for slicing the specimens in order to maintain smooth surface with less heat affected specimens which were later processed to measure microhardness and weld bead geometry. The prepared specimens were etched using two different agents to get clear bead geometry. Hence the specimens were etched in aquaria (40% concentrated nitric acid and hydrochloric acid) for a dwell time of 6s, which is an aggressive reagent and later the aggressively etched specimens were once again etched in natural (40% concentrated nitric acid and ethanol) for a dwell time of 15s. The combination of aggressive and soft etching provided a clear macrostructure which was captured using Nikon 5200 digital camera. The captured images were used to measure the bead geometry of depth of penetration (DOP) and bead width (BW). Based on the depth of penetration (DOP), the desired value of welding speed 250 mm/min and welding current 90A for welding 1.6mm thick SS316Lwas chosen. The selected value of welding speed and the welding current was maintained to perform butt joint in SS316L 1.6mm sheet. The face and root side of butt joint are shown in figure 3a and figure 3b.

Figure 3 (a): Root of the TIG Welding of Butt Joint on SS316L

Figure 3 (b): Face of the TIG Welding of Butt Joint on SS316L

Table 2: Welding Parameters of SS316L

Input Parameters of Gas Tungsten arc welded SS316L Sheets			
Trail No.	**Welding current (A)**	**Welding speed (mm/min)**	**Heat input (J/mm)**
1	70	250	302.4
2	90	350	432
3	110	450	554.4
4	70	250	216
5	90	350	293.1429
6	110	450	377.1429
7	70	250	168
8	90	350	228
9	110	450	293.3333

RESULTS AND DISCUSSIONS

Wire cut EDM was used to get a flat dog bone shape tensile specimen. The specimen dimensions of 12.50mm width, 95mm of parallel length and 200mm of overall length were made according to ASTM E8 standards. The tensile test was performed with the position rate of 1mm/min at an atmospheric temperature (27°C). The 50KN Tinius Olsen universal testing machine with manually locking grips was used to conduct tensile fracture test. During the test, the uniform incremental axial load was applied in order to get the stress-strain values which were used to determine the tensile strength and elongation at failure. The tensile tested samples were visually evaluated and noted that a fracture occurred in the base material area of the welded sample. The results of tensile tests showed that tensile strength and total elongation for base metal was found to be 549MPa and 112% and for the welded sample was found to be 566MPa and 72.9%. The welded sample has better tensile strength than base material and the plastic deformation of the base material is greater than the welded sample, which shows that ductility of the base material was traded while welding to improve the tensile strength in the welded specimen as the result of excessive strain hardening due to homogeneous phases in the welded specimen. The tensile strength of welded metal and base metal are shown in figure 4.

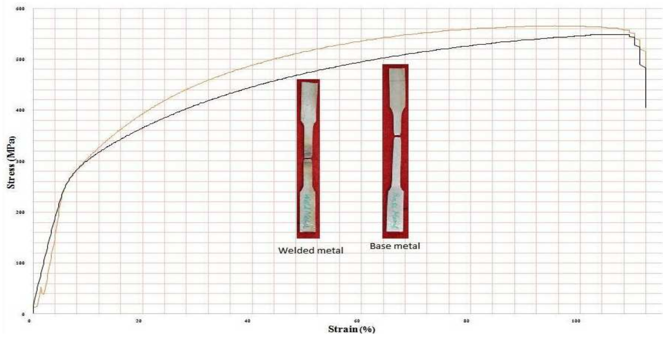

Figure 4: Stress-Strain Graph used to Determine the Tensile Strength of Base and Welded Material

The low heat input parameter of trial number 7 and highest heat input parameter of trial number 3 was subjected to measure the microhardness distribution values. Dwell time of 15 seconds and a load of 500 grams was maintained in Vickers microhardness tester. The low heat input parameter trial results with average Vickers microhardness values of 208, 232.9 and 256.1 on BM (Base Metal), HAZ (Heat Affected Zone) and FZ (Fusion Zone) respectively. The highest heat input parameter trial has average Vickers microhardness values of 209.8, 235.6 and 266.3 on BM, HAZ and FZ respectively. Even though the fusion zone has a coarse grain structure, the hardness is higher than the HAZ and BM zones. HALL PETCH effect-states that the size of grains plays a significant role in the hardness of the materials. Smaller grain size leads to higher hardness as it leads to the more grain boundaries on the path of crack propagation so in return the different orientation of the grains in the region prevents the crack from propagating as it prevents the spreading of slip planes. The fusion zone has a coarse grain structure due to epitaxial solidify. Cooling of weld zone occurs from BM to the surrounding HAZ and from their cooling occurs in the center of the weld zone. The type of solidification mainly depends upon the composition of the weld zone. Autogenous GTAW was used to perform trial hence mostly FZ, HAZ and BM have similar chemical composition after welding which leads to epitaxial solidification. The partially melted grains in the heat affected zone solidified and grow to complete the whole grain and then it grows in the direction towards the fusion zone as the liquid metal solidifies. This results in the formation of the coarse grain structure in the fusion zone. The coarse grain structure of FZ is formed due to prolonged cooling time from high temperature, similarly, these factors led BM and

HAZ achieve fine grain size. Even though the precipitation of other elements in fusion zone is higher compared to BM and HAZ which resists the propagation of slips across grain boundaries which increases the hardness in the fusion zone. The microhardness distribution of trial 3 and 7 are shown in figure 5.

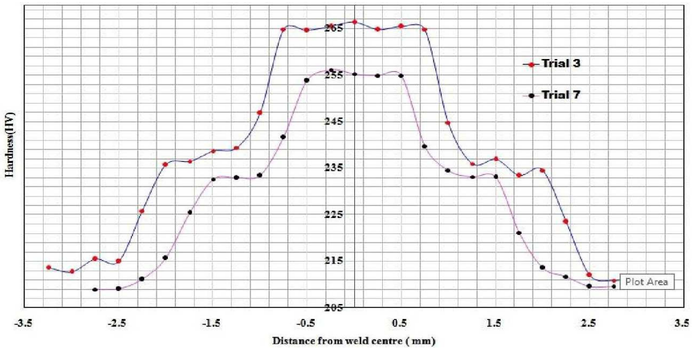

Figure 5: Micro-Hardness Graph of Two Parameters

CONCLUSIONS

From the characterizations of gas tungsten arc welded SS316L sheets, the following conclusions can be withdrawn

The results of tensile tests showed the tensile strength and total elongation of base metal were found to be 549MPa and 112% and for the welded sample was found to be 566MPa and 72.9%. The ductility of the base material was compromised to improve the tensile strength of welded specimen due to excessive strain hardening in the welded specimen.

The low heat input parameter results with average Vickers microhardness values of 208, 232.9 and 256.1 on BM, HAZ and FZ respectively. The highest heat input parameter results with average Vickers microhardness values of 209.8, 235.6 and 266.3 on BM, HAZ and FZ respectively.

The coarse grain structure of FZ is occurred due to long cooling and high temperature, and comparative slow cooling rate led BM and HAZ achieve fine grain size. The precipitation of other elements in fusion zone is higher compared to BM and HAZ which are a resistance to the propagation of slips across grain boundaries, which increases the hardness in the fusion zone.

REFERENCES

1. *R. R. Mishra, V. K. Tiwari, and S. Rajesha, "A Study of Tensile Strength of MIG and TIG Welded Dissimilar Joint of Mild Steel and Stainless Steel," Int. J. Adv. Mater. Sci. Eng., vol. 3, no. 2, pp. 23–32, 2014.*

2. *S. Sharma, "Study of Mechanical Properties in Austenitic Stainless Steel Using Gas Tungsten Arc Welding (GTAW)," vol. 3, no. 6, pp. 547–553, 2013.*

3. *W. Chuaiphan and L. Srijaroenpramong, "Effect of welding speed on microstructures, mechanical properties and corrosion behavior of GTA-welded AISI 201 stainless steel sheets," J. Mater. Process. Technol., vol. 214, no. 2, pp. 402–408, 2014.*

4. *Vipul M Vasava et al., , Design and Analysis of Wireless Welding Arm, International Journal of Mechanical and Production Engineering Research and Development (IJMPERD), Volume 6, Issue 4, July - August 2016, pp. 9-24*

5. *A. P. Shinde, A. R. Deshpande, S. S. Chinchanikar, and A. P. Kulkarni, "Evaluation of Tensile Strength of a Butt-Welded Joint Considering the Effect of Welding Parameters Using Response Surface Methodology," Mater. Today Proc., vol. 4, no. 8, pp. 7219–7227, 2017.*

6. *C. Muthusamy, L. Karuppiah, S. Paulraj, D. Kandasami, and R. Kandhasamy, "Effect of heat input on mechanical and metallurgical properties of gas tungsten arc welded lean super martensitic stainless steel," Mater. Res., vol. 19, no. 3, pp. 1–12, 2016.*

7. *Sundari S et al., , Finite Element Simulation and Experimental Study of Stretch Formability of Super Duplex Stainless Steel Sheet , International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) , Volume 6, Issue 4, July- August 2016, pp. 1-8*

8. *S. Kumar and A. S. Shahi, "Effect of heat input on the microstructure and mechanical properties of gas tungsten arc welded AISI 304 stainless steel joints," Mater. Des., vol. 32, no. 6, pp. 3617–3623, 2011.*

9. *L. ZHAO, Z. ling TIAN, Y. PENG, Y. chang QI, and Y. jie WANG, "Influence of Nitrogen and Heat Input on Weld Metal of Gas Tungsten Arc Welded High Nitrogen Steel," J. Iron Steel Res. Int., vol. 14, no. 5 SUPPL. 1, pp. 259–262, 2007.*